Native Bees on Columbia County Farms and Floodplains

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Introduction

Bees are essential pollinators for most of our crops and vegetables. The number of domestic honey bee colonies has declined greatly during the past half century in the United States. Due to the diminished number of honey bees, more attention is being given to the largely unknown and overlooked wild native bees. Managing for native pollinators in a variety of ways may become an important aspect of sustainable agriculture. Researchers have found that on some diverse farms the majority of crop pollination is done by native bees and not honey bees. For this reason I believe it is important to study wild bees in the context of farm environments.

Relatively little is known about native bees in the Northeast. I hope that by learning about these on-farm bees, there will be the potential to manage for them and positively impact their populations. In order to help and manage for native bees one must first understand their ecology.

Through my senior project, a study of wild native bees on farms, I hoped to learn what types of bees pollinate which plants regionally, and how consistent pollinator/crop relations are across farms. Another goal of this project was to familiarize local farmers with native bees. Many farmers are not aware of the potential crop pollination services native bees can provide. I therefore aimed to create a baseline of bee data for different farms that may allow people to assess changes in bee communities in the future.

During the end of 10^{th} grade I attended a workshop on wild bees at the University of Connecticut with Conrad Vispo. This workshop sparked my interest in native and wild bees. I began researching bees on farms throughout the summer that followed. During 11^{th} grade I gave a presentation with Mr. Vispo about bees and the research conducted during the summer. We gave this presentation at The Nature Institute to a beekeepers club. In the spring of 11^{th} grade I traveled to Maryland with Mr. Vispo to meet with Sam Droege, a bee expert at the Patuxtant Wildlife Research Center. He looked at the bees I had collected and identified the ones I could not. The following week I presented a poster on my bee research along with Mr. Vispo at the Northeast Natural History Conference in Albany, NY. At this conference scientists gave both oral presentations and poster presentations on their research. I was available with my poster to answer any questions. Mostly professional scientists, undergraduate and graduate students presented posters. Out of the 30 student-made posters, mine was nominated as one of the top ten finalists.

Toward the end of 11th grade I decided that I wanted to continue the bee research for my senior project, and Mr. Vispo agreed to be my mentor. Mr. Vispo has a Ph.D in wildlife ecology and is the coordinator of the Farmscape Ecology Program, which among other things studies wildlife on farms. Mr. Vispo became involved in bee research one year before I began studying bees with him.

At the start, researching bees was rather frustrating, especially the identification--I could not even distinguish some flies and wasps from bees. To identify the bee species or even genus can be extremely difficult. In fact, even experts have a hard time identifying certain groups of bees, which is not surprising considering that there are over 420 species in New York State alone, and around 3,500 species in North America. However, after many hours of identification the work slowly started becoming more fun because at least I could identify some of the easier bee groups. My project also became easier and more enjoyable as I spent time reading about bees and their importance as pollinators.

During the summer of 2008, I went out often to collect bees and conduct research on farms. Because I already had experience from the previous summer I did not need to go out with my mentor any more and was able to do most of the work myself. During the school year I met with my mentor usually once a week for several hours and also continued doing a lot of work, mostly identification, on my own.

Floodplain Forest Research

I conducted similar research during the summer of 2007 to what I did in 2008, except that during 2008 I greatly expanded my study and the work. In addition to the on-farm research, during the spring of 2008 I collected bees in floodplain forests (forests along streams that are usually rich in wildflowers in early spring). There is a great diversity and abundance of bees in these early spring forests. Many of these native bees are only active adults during the spring and therefore would not be found during the summer and may rely heavily on these floodplain habitats for survival; conversely spring plants need them for pollination.

In order to identify wild bees, the bees must be dead so one can view them under a microscope. It is important to identify the bees, because the biology of the different species varies immensely. For instance, one small black bee might look very similar to another. However, one of them may nest in wood and the other in the ground, which makes a big difference if one is attempting to help conserve them. When one collects bees one impacts the bee populations little, if at all, because only a negligible percentage of the population is taken. I believe I can justify killing these bees because, by learning more about them, eventually we can become more sensitive to their needs and learn which habitats are crucial to their conservation.

I collected bees in the floodplain forests by putting out 3.5 ounce colored cups or "bee bowls," alternately using white, florescent blue, and florescent yellow. I put 15 bowls out in a straight row (along a transect) 5 meters apart from each other. These cups are filled with soapy water and are left out for 24 hours. The bees are attracted to the cups, presumably because they see them as flowers and then drown in the water. I used this method because it is standardized, meaning that I can compare the number of bees caught across sites. Additionally, other bee researchers also use this method, so in the future I can compare my results with theirs. I collected bees in five different floodplain forests all in Columbia County, while the early spring wildflowers were out. At each forest I put out a total of at least 45 bowls. After 24 hours I came back to collect them. I found that bees were particularly abundant in these floodplain forests. Certain bee species were only found in floodplain forests and were not found on farms. However, many of the species were found in both habitats. This could indicate that floodplain forests are beneficial for the specialist bees that need this particular habitat and the flowers that grow in it. In addition, the floodplain forests also provide habitat for more common bees which are important crop pollinators later in the season.

On-Farm Research

I researched bees on four different farms: Hawthorne Valley Farm, Little Seed Gardens, Roxbury Farm, and Thompson Finch Farm. I collected data on farms in three different ways: bee bowls, netting, and visual surveys. The bee bowls method was the same as used in the floodplain forests. I put rows of bowls along crops that were in flower. Additionally I put out bowls in more natural habitats such as fields, forest edges, and wildflower meadows. I visited each of the farms at least once throughout the summer, putting out a minimum of three bowl transects along crops and three transects in natural areas, for a total of at least 90 bowls at each farm.

I also caught bees with a net. There are several benefits to netting. With a net one can catch certain larger bees such as bumblebees that rarely get caught in the bowls. Additionally, I netted bees directly off of crop and wildflower flowers, which allowed me to identify individual bee species that were visiting and probably pollinating certain crops and wildflowers. For example, by netting I was able to catch certain bee species off of squash flowers. It turned out that this species was actually a squash specialist called *Peponapis pruinosa*. By having netted it on the squash flowers I could verify that it had been visiting this particular crop, which may partially rely on *P. pruinosa* for pollination services. It is very difficult to standardize netting techniques; therefore I cannot reliably compare my results of netted bees across the different farms.

Overall, netting bees is much more time consuming and labor intensive than catching bees in bowls because it often takes quite a while to find and catch just a single bee. Often I caught only 5 or so bees in an entire hour of netting, while I could put out, pick up, and record site data for 15 bowls in less than half an hour. On average I caught about one bee per bowl and sometimes as many as three. Bee expert Sam Droege found that on average one catches about 0.5 bees per bowl, which may indicate that the farms I studied actually have relatively high native bee abundance.

A day or two after I collected the bees I pinned them. The bees I netted were killed in a jar charged with ethyl acetate, a poison which kills the bees very quickly. These bees were dry so

I could directly pin them. The bees caught in the bee bowls were wet, so before I could pin them I needed to wash and dry them. I did this by first placing the bees in clean soapy water and swirling them around and then I used a hair dryer to dry them. Blow drying un-mats the bees' hairs and wings, making identification much easier.

To pin the bees I gently placed the dead bees on foam and impaled them using special insect pins. This allowed me to view the bees from all angles under the microscope. After the bees were pinned I attached labels to each pin. The label provides the date and location in which the bee was caught as well as how the bee was collected (bowl or net). If a bee was collected on a flower the flower species was given on the label and if the bee was caught in a bowl the particular transect was noted on the label. These labels correlate with my notes, in which I recorded additional information, such as the exact collecting location (established using a global positioning system), weather while collecting, and site description. For the bowl transects along crops I also noted which plant species were in bloom within 20 meters of the transect and their relative abundance on a scale from 1-5. I have yet to analyze this flower data, but it may help me see if wildflowers around crops attract bees or not.

For my visual surveys I did not need to catch or kill any bees. Each survey consisted of me observing a certain plant species' flowers for 10 minutes and recording the number of bees, flies, and wasps I observed on the flowers. I walked along a crop row such as a row of tomatoes, and observed the flowers and looked for bees for a period of ten minutes. I also observed clusters of wildflowers and weeds for ten minutes at a time. When I recorded the bees, I also noted which general group they fit into. I categorized bees as honey bees or wild bees and if they were wild bees I noted whether they were squash bees, bumble bees, metallic green sweat bees, or other wild bees. Without looking at the bees under a microscope it was not possible to identify them any more precisely than that, which is a limitation of visual surveys because it is impossible to accurately identify almost all of the wild bee species from a distance. However, visual surveys are very helpful for comparing the number of native bees versus the number of honey bees visiting flowers. This can give an indication of whether honey bees or native bees are more significant crop pollinators.

During the spring and summer of 2008 I collected over 1,200 bees. After I pinned and labeled all of them I set out to identify them, which was the main part of my work during this past fall and winter. Identification consists of looking at the bee specimens under a microscope and going through an online identification key. The bee identification keys I used (www.discoverlife.org) were largely developed by Sam Droege. The reason that identification is so difficult is that one must pay attention to very subtle characteristics, many of which take experience to observe.

As an example I will go through the various characteristics one needs to observe in order to identify the very common green sweat bee *Augochlorella aurata*. Assuming that one knows it is a bee, one must look and see whether there are two or three submarginal cells in the wing (two or three rectangular areas surrounded by veins), additionally one must note that the foremost wing vein is strongly curved, not slightly curved or straight. Then one must note that the bee is metallic green not dark dull green. The next characteristic is that the bee does not have a raised carina (a raised rim) on the back of the thorax. Also, the base of the wing is oval not D shaped. Lastly, another wing vein is pointed, not slightly "truncate" and the "paraocular lobe extends down into clypeus at an obtuse or right angle" and not at an acute angle (a hard-to-describe facial character). It should be noted that this species is actually quite easy to identify compared to most, and it is the only species in this genus found in New York State. Other genera have over fifty species in them, in which case identifying individual species can be far more difficult. There are many species that I still cannot identify. However, I could identify all the genera and many of the species I collected. In fact, when Sam Droege looked over my bees only a few were misidentified (however, I left many unidentified to the species level).

During February, I went to Maryland and Sam Droege was kind enough to look over all the bees I had collected. Afterwards, I started entering the individual bee specimen data I had collected on farms into an excel spreadsheet. For each location (e.g. transect or netting location), I recorded the exact coordinates and entered them into the spreadsheet. I will now send this data to Sam Droege, and he will make it available on the discoverlife.org website maps. So if one looks up *Bombus impatiens* for example, one will see the location of Hawthorne Valley Farm on the map showing where it has been collected, as well as the date and time of collection and any additional specific information I may have noted.

The vast majority of the bee species that I collected have never before been recorded in Columbia County (or at least they were not entered into the vast discoverlife.org database). Therefore, at the very least, my research helps show where certain species occur so one can start establishing range maps and in the future track bee ranges to see if they are changing and see whether the native bee populations are declining or stable, which is largely unknown.

In 2007 and 2008 I collected the species listed below on farms and in floodplain forests in Columbia County. Numbered species are ones in which the species names were not identified, but they are all distinctly different species. Altogether I collected 114 species (including two species that were only collected along a power line cut near a floodplain), with 83 species collected on farms, and 56 species collected in floodplain forests.

Table 1. Species List:

Agapostemon texanus
Agapostemon virescens
Andrena alleghaniensis
Andrena carlini
Andrena crataegi
Andrena cressonii
Andrena erigeniae
Andrena fragilis
Andrena nasonii
Andrena nuda
Andrena pruni
Andrena sp.1
Andrena sp.2
Andrena sp.3
Andrena sp.4
Andrena sp.5
Andrena sp.7
Andrena sp.8
Andrena sp. 9
Andrena sp.10,
Andrena sp. 11
Andrena sp.12
Andrena wilkella
Anthidium oblongatum
Apis mellifera
Augochlora pura
Augochlorella aurata
Augochloropsis metallica
Bombus bimaculatus
Bombus citrinus
Bombus fervidus
Bombus impatiens
Bombus pensylvanicus
Bombus perplexus
Bombus ternarius
Bombus vagans
Calliopsis andreniformis
Ceratina calcarata
Ceratina dupla
Ceratina strenua
Colletes inaequalis
Halictus confusus
Halictus ligatus
Halictus rubicundus
Holcopasites calliopsidis
Hoplitis producta
Hoplitis spoliata
Hylaeus affinis
Hylaeus mesillae
Hylaeus sp. 1,
Hylaeus sp. 2,
Hylaeus sp. 3,
Lasioglossum admirandum
Lasioglossum anomalum
Lasioglossum atlanticum
Lasioglossum bruneri
Lasioglossum carlini
Lasioglossum cattellae
Lasioglossum cinctipes
Lasioglossum coriaceum
Lasioglossum cressonii
Lasioglossum cressonii
Lasioglossum crossoni
Lasioglossum foxii
Lasioglossum imitatum
Lasioglossum laevissimum
Lasioglossum leucozonium
Lasioglossum lineatulum
Lasioglossum macoupinense
Lasioglossum nymphaearum
Lasioglossum obscurum
Lasioglossum pectorale
Lasioglossum perpunctatum
Lasioglossum pilosum
Lasioglossum planatum
Lasioglossum quebecense
Lasioglossum rohweri
Lasioglossum subviridatum
Lasioglossum tegulare sensu lato
Lasioglossum truncatum
Lasioglossum versans
Lasioglossum viridatum group
Lasioglossum zephyrum
Lasioglossum zonulum
Lasioglossum zophops
Megachile latimanus
Megachile mendica
Megachile montivaga
Megachile relativa
Megachile rotundata
Melissodes bimaculata
Nomada bidentate sp. A
Nomada bidentate sp. B
Nomada bidentate sp. C
Nomada depressa
Nomada white spine 1
Nomada wt sp. 2
Nomada wt sp. 3
Osmia atriventris
Osmia bucephela
Osmia cornifrons
Osmia lignaria
Osmia pumila
Paranthidium jugatorium
Peponapis pruinosa
Perdita halictoides
Sphecodes heraclei
Sphecodes sp. A,
Sphecodes sp. B
Sphecodes sp. C
Sphecodes sp. D
Xylocopa virginica

Bombus fervidus

Bombus perplexus

Ceratina sp.

Agapostemon virescens

Paranthidium jugatorium

Melissodes bimaculata

Calliopsis andreniformis

Andrena carlini

Bombus ternarius and *Lasioglossum imitatum* (size comparison)

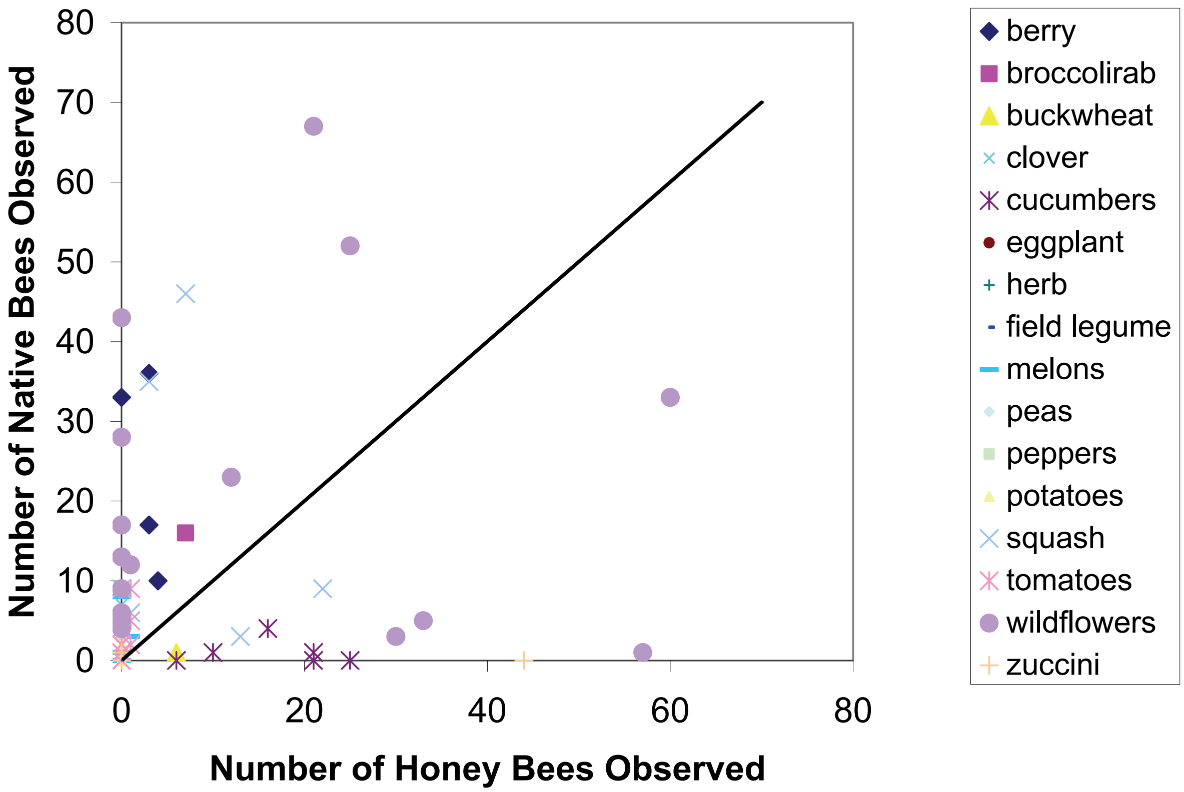
Table 2. The number of native bee species per farm and their abundance:

Farm	# Native Bee Species	Average # Native Bees Per Transect
Hawthorne Valley Farm	20	21.7
Farm at Miller's Crossing	22	17.1
Roxbury Farm	24	12.3
Little Seed Gardens	19	14
Thompson Finch Farm	29+	18.8

The data in Table 2 is only based on 2008 bowl collection and does not take into consideration bees that were netted or bees collected in 2007. Additional collecting was done at Thompson Finch Farm in the spring with a total of 39 species collected in bowls.

This table illustrates that I did find some variation across farms, perhaps the most significant was the variation in the average number of bees collected per transect on the different farms (average number of bees caught per 15 bowls on a given farm). This variation in bee abundance across farms may be due to collection biases, such as slightly warmer or otherwise better weather (collection and visual surveys were not done during inclement weather). However, it may also be due to variation in land use or landscape. For example, the amount of natural habitat such as wildflower meadows or hedgerows surrounding the crop fields could impact the amount of bees present. The amount of wildflowers in the crop fields themselves may also impact the bee populations on these farms.

Table 3. Honey Bee vs. Native Bee Abundance on Flowers:



I found in my visual surveys that native bees tended to be a little more common than honey bees on flowers. Table 3 shows my results for the 2007 and 2008 visual surveys I conducted. Each point on the graph represents a different 10-minute survey.

Table 4. Average Honey Bee vs. Native Bee Abundance on Specific Crops:

Plant	# Honey Bee Visits	# Native Bee Visits
berry	2.5	24
cucumbers	12.4	1.4
melons	0.3	3
peas	0	0
potatoes	0	2
squash	4.6	11.5
tomato	0.3	2.3
wildflower	14.9	20.06
zucchini	11	0.3


Table 4 shows the average number of honey bee and native bee visits for all of the plants for which I conducted more than one survey. During 2007 and 2008 I conducted a total of 70 visual surveys, and I observed a total of 619 native bee flower visits and 415 honey bee visits. As indicated earlier, this shows that, overall, native bees tended to be more common pollinators than honey bees. These are somewhat reassuring findings, suggesting that if honey bee populations continue to decline, crops on small diverse farms, such as the ones studied, will continue to receive adequate pollination services.

On March 24, 2009, I gave a presentation about my bee research in Harlemville, NY. This 45 minute presentation was geared toward the farmers of the farms where I had done my research; however, it was open to the public and approximately 25 people attended. The goal of this presentation was not only to show the results of my study, but also to familiarize people with native bees by showing them photographs and giving them an overview of native bee biology. An underlying theme of the talk, highlighted by my results, was how beneficial native bees can be as crop pollinators. I then discussed different ways that one can help conserve native bees through landscape management.

Conclusion

I enjoyed this project very much. It was often difficult, and I don't think I would be as satisfied with the results had I not started in 2007. I learned many skills by doing this project, such as how to set up a scientific study and how to record data. I have gotten a feel for how scientific studies must be conducted so they are repeatable and statistically sound and thus allow for comparisons to be made. I also learned the specific skills required to catch bees, and how to identify many different bees, which is very difficult. I imagine that identifying bees is similar to identifying some other insect groups, so I can use some of the knowledge I gained to identify other insects. Through presenting my bee poster and research, attending two conferences on bees and meeting other biologists, I have gained a better sense for the scientific community and the various possible avenues of work in this field.

If I were to do this project again, I would probably spend additional time collecting bees in other habitats to find additional species. Other than that, my project went just as I had hoped. I am very happy that I chose to study native bees for my senior project and it will continue to be an interest of mine.

Acknowledgements

Foremost I would like to thank my mentor Conrad Vispo for enabling me to do this project and for being the first person to introduce me to native bees. Mr. Vispo and the Farmscape Ecology Program also provided me with all of the equipment I needed to collect and identify the bees. I am also indebted to Sam Droege for looking at all the bees I collected, verifying and identifying them. Without him this project would not be nearly as credible, and many of the bees would not have been identified.

Research Paper:

Native Bees and Their Role in Pollination

Introduction

Native bees are increasingly valued pollinators of agricultural crops as European honey bee abundance decreases. By understanding native bee biology we may be able to learn landscape practices that benefit them. Many people are unaware that in addition to the introduced honey bee a large community of native bees also exists. However, these native bees can provide significant pollination services for both crops and wildflowers, which may be of growing importance if honey bees continue to decline as they have been over the past half century.

Overview of Pollination

Pollination is the first step toward fertilization and subsequent seed set for a plant. For pollination to occur, the pollen (from the stamen, the male part of the flower) must somehow be transported to the pistil (which is part of the plant's female reproductive system). Depending on the type of plant, the pistil and the stamens can either be in the same flower, or on different flowers. Often for plant populations to be healthy and strong, cross pollination must take place. For this to take place, the pollen from one plant must come in contact with pistil of another plant.

The most common forms of pollination are wind and insect-mediated. Additionally, mammals, including bats and mice, do occasionally pollinate flowers, however, in most regions their pollination services are negligible. Grasses, including grains such as wheat and corn, are wind pollinated, which means that the wind carries the pollen from one flower to another. Wind-pollinated plants must create lots of pollen to increase the chance that some of the pollen reaches another plant. Indeed, some very interesting wind pollinated plants have developed ingenious structures around the flowers that channel the wind and subsequent pollen towards their flowers, which increases their chance of being pollinated (Buchmann and Nabhan 1996).

About 35% of the world's crops are pollinated by animals, primarily insects (Vaughan et al. 2007). Approximately one in three bites of food is either directly (e.g. if your eating a vegetable, which was a result of insect pollination) or indirectly (e.g. if your eating beef from a cow that was eating a plant that required insect pollination) a result of insect pollination. Bees are by far the most important and best insect pollinators. Many crops require or are benefited by insect pollination. These include strawberries, blueberries, cranberries, apples, citrus fruits, cherries, peaches, plums, pears, almonds, squash, zucchinis, pumpkins, melons, peppers, tomatoes, carrots, canola, sunflower, and also clover, buckwheat and alfalfa which are forage crops (Stankus 2008, Winfree et al. 2007b).

Honey Bees

Honey bees are perhaps one of the most well known insects. Honey bees have a very different biological life history than the native bees found in North America. They were not present in North America before European settlement. The settlers introduced honey bees in the early 1600s (Buchmann and Nabhan 1996). Now honey bees can be found almost everywhere on earth. Honey bees have very complex and sophisticated social structures. They form perennial colonies of up to around 50,000 individuals. Honey bees are valuable pollinators for a variety of reasons, including their transportability, great numbers, their ability to direct each other to flower sources, and because they visit a vast array of different flowers.

When many people think of the benefits of honey bees they generally think of the honey they produce. However, their crop pollination services are actually of far greater value. In the United States approximately 161 million dollars worth of honey are produced annually (Stankus

2008). However, in North America honey bees provide an estimated 14.8 billion dollars worth of pollination services annually (Winfree et al. 2007b).

Honey bees are such valuable crop pollinators in part because they can be transported in great numbers to crops in flower that need their pollination services. Consequently, many farms (mostly conventional) rent hives during the time their crops are in bloom. These hives over winter in the south and then are trucked to where they are needed. For example, during the almond bloom in California, massive numbers of honey bees are trucked in for a short period before they are moved to another crop where their services are required. Many of the agricultural landscapes where the honey bees are needed are homogenous, dominated by a single crop species, with very little natural habitat. The honey bees are absolutely crucial in these landscapes for crop pollination because these homogeneous landscapes cannot support native pollinator communities.

Even given the undisputed pollination value of the honey bee, some researchers (eg Goulson et al. 2003) believe that it is unsafe to rely entirely on one species to provide all the crop pollination services needed. They believe this is unsafe because, if the sole pollinator declines or suffers from some epidemic then a great extent of our food supply would be in jeopardy.

Unfortunately over the past half century there has been a stark decrease in honey bee populations. In fact, today in the United States there are 59% fewer managed honey bee colonies than in the early 1950s. In the recent few years honey bees have suffered unprecedented declines. In 2006-2007 in the United States, 29% of beekeepers reported honey bee declines of up to 75%. Many of these recent honey bee declines have been attributed to Colony Collapse Disorder (CCD), which is a new occurrence (Winfree et al. 2007b).

CCD is characterized by mass disappearances of honey bees from their hives. Usually the bees are never found but presumably large numbers die away from the hives. CCD has been reported from many areas in North America and could be occurring elsewhere as well. No one is really sure what causes the CCD. However, it is likely a conglomerate of different diseases and stressors acting on each other. Beekeepers have long been aware of various viruses and mites that kill their bees, but only in recent years have honey bees been entirely disappearing (Stankus 2008).

Shipping honey bees across the country may weaken them. They are often brought to pollinate a single crop. On industrial scale farms with one crop in flower, little if any natural habitat, and good weed control, the honey bees only have one pollen and nectar source. Depending on the type of crop this monoculture may lead to a nutritionally deficient diet for the bees, which could further weaken them. Additionally, most of these industrial scale farms spray pesticides. Beekeepers may find thousands of dead honey bees around their hives after a significant kill from pesticides. Sub-lethal doses of pesticides may also stress honey bees in a variety of ways. Poisoned honey bees can become disoriented and cannot find their way back to the hive (Shepherd et al. 2003).

Mites attack honey bees both internally and externally. Viruses also cause great harm to honey bees. Some viruses cause the wings to form in such a way that they are nonfunctional, while others paralyze the bees. Viruses and mites are considered to be some of the most significant contributors to the mysterious disappearances of honey bees (Stankus 2008). It seems that over the years honey bees have been stressed and treated in many unnatural ways and consequently we must now face the consequences of CCD.

Native Bees: Overview and Biology

Unlike honey bees, native bees are indigenous to this continent. However, there are also some species of wild bees that have recently been introduced to North America. Over 19,000 bee species occur globally (ITIS), with 423 species documented in New York State (Giles and Ascher 2006). Even in New York State there is a great diversity of bees, from the large well known carpenter bees and hairy bumble bees, to tiny less-well known bees that are only a few millimeters in length. Many people confuse small native bees with wasps and vice versa. However, bees collect only nectar and pollen for themselves and their young, while wasps kill other insects to feed their young. Additionally most female bees have specially developed pollen collecting hairs (scopa) or pollen baskets, wasps and male bees lack these structures. However, there are exceptions to this rule. Some bees are parasitic, and lack these structures. Cleptoparasitic bees for example, invade other bees' nests, kill their larvae, and lay their own eggs on top of pollen masses already provisioned by the host bee (O'Toole and Raw 1991). Additionally, there are some native bees that collect pollen and carry it internally, instead of on scopa or pollen baskets (Packer et al. 2007).

Native bees in North America have very different life histories and habits than honey bees. Native bees do not live in hives. Most native bees live in excavated burrows in the ground while others excavate tunnels in wood or nest in hollow stems. Bees have several life stages, first the egg is laid. Out of the egg hatches a larva, which is small and worm-like. The larva eats the food that has been provisioned for it. Then it pupates, metamorphoses into the adult form and finally breaks out of its cell. This process is similar to how a caterpillar metamorphoses into a butterfly.

Approximately 60% of the bee species found in New York State are ground nesting (Danforth et al. 2002). Ground-nesting bees excavate tunnels in soil, often choosing somewhat sandy, well drained soil with sparse vegetation and direct exposure to sunlight. Coming off the main, often vertical, tunnel, the bees excavate little cells. They provision these cells with "bee bread." The bees first visit flowers and collect pollen and nectar (the nectar is carried internally) and then fly back to their nest. When the bee is back at the cell she is provisioning, she creates bee bread by packing the pollen and nectar into a dense mass. She then lays an egg on top of this pollen mass, seals off the cell, and begins provisioning the next. A female may only lay a few eggs in her lifetime (Shepherd et al. 2003). Consequently, populations of native bees (as opposed to some other types of insects) recover slowly after they have been eradicated from an area. For example, if pesticides are repeatedly applied to an area, or if the ground in which a large aggregation of bees are nesting is tilled, the bee population may not recover so quickly.

Wood-nesting bees provision their cells in a similar manner. Their cells are situated one after another in their cavity. The female often lays eggs destined to become males in the last three or so cells closest to the entrance, these males emerge before females do. Bees and some other related insects have the unique biological trait that they can determine the sex of their offspring. When a female bee mates with a male she captures the sperm (she is then inseminated) and can either fertilize her egg, which would then develop into a female, or not, in which case the egg would develop into a male. Consequently, unmated bees can lay eggs, but the eggs will only become males.

Some species of bees have nesting habits that differ from these two basic kinds. For example, several species of bees nest in abandoned snail shells (O'Toole and Raw 1991).

Sociality of Native Bees

Native bees have many levels of sociality, ranging from solitary (the majority of bees) to primitively social (i.e. bumble bees). Many intermediary forms occur among species and even a single species can have a range of sociality. In contrast, honey bees are obviously highly social.

In solitary species, a female creates cells in any of the above-mentioned ways and provisions them herself. After provisioning the cells she dies, before her offspring emerge. Other bees are slightly more social, in that the females tolerate nesting near each other. In some cases the females share nest entrances but do not interact in any other way, they are communal. Many bee species are sometimes communal (O'Toole and Raw 1991).

In semi-social bee species, several females inhabit the same nest. However, some of the females have enlarged ovaries and perform the majority of the egg laying. In this case there is a simple division of labor. Some bees lay eggs while others perform more the foraging duties. Some sweat bees (Halictidae) are primitively eusocial. In these species, the females who mate in the fall lay eggs in the spring, just like solitary female bees do. Later in the season their daughters emerge and help with foraging, nest guarding, and constructing cells, the colony then becomes primitively eusocial (O'Toole and Raw 1991)

Bumble bees are also primitively eusocial (except for a few parasitic species). Much like honey bees, bumble bees have a large queen and smaller worker females. Queens mate in the fall and then hibernate, the queens are the only bumble bees that overwinter. In the spring the queens find a place to for a nest, either above ground or underground. As her daughters emerge they take over much of her foraging activities. The colony then grows throughout the summer. The queen is the primary egg layer. At the end of summer some males are produced. These males mate with new young queens which then over winter and the cycle begins again. Queens emerge out of larger cells, which were provisioned with more food. In contrast to honey bees, bumble bee colonies are annual and usually only contain twenty to several hundred bees (Kearns and Thomson 2001).

Unlike honey bees, some native bees are not generalists and only visit one species, or a group of related species, of flowers to collect pollen. These bees may visit other flower species to collect nectar. These bees are known as specialist or oligolectic bees. For example, *Peponapis pruinosa* is a ground nesting squash specialist. It exclusively collects pollen from plants in the squash family. Specialist bees are almost always solitary and their life cycles coincide with that of the flowers they visit. Oligolectic bees are found most commonly in extreme environments such as deserts. Over 60% of the bee species found in deserts of North America are oligolectic (O'Toole and Raw 1991). However, only about 20% of bee species in the northern United States are oligolectic (Danforth et al. 2002).

Case Study: Halictus ligatus

Halictus ligatus is a well-studied, common primitively eusocial sweat bee, found in southern Canada and most of the United States south to Venezuela (Litte 1977). These bees are black and considerably smaller than honey bees (3/8 in vs. ¾ in long). *H. ligatus* "foundresses" (referred to by some as "queens") are born and emerge in late summer and fall. Before winter hibernation the foundresses mate. Hibernation usually takes place in the foundresses's maternal nest, which is in a small network of tunnels and cells in the ground. After overwintering these inseminated females begin to emerge in early May and begin nests in sparsely vegetated, well-drained ground. Quite a bit of variability occurs in this species and nests are either founded by one female, two or three females (Packer and Knerer 1986). However, before the foundresses start laying eggs or provisioning cells for their offspring, they excavate temporary cells for themselves. The foundresses excavate these cells for the week or so after they emerge, when they are only collecting pollen and nectar for themselves. After completing the excavation of a new nest or the repair of an older one the foundresses provision the cells with pollen. The small cells are each for an individual egg. She secretes a substance from the Dufour's gland and lines the cell with it, which makes the cells relatively water proof, keeping contents from getting too wet or too dry. She carries the pollen into the cell. After bringing several loads of pollen she molds it into an oblong mass and adds some nectar. An egg is then laid on top of the pollen mass and the cell is plugged. The foundresses usually create five or fewer such cells before the workers emerge. The daughters (workers) emerge a couple weeks later. The workers tend to be smaller then the foundresses. The foundress lays eggs throughout the summer, and also guards the nest entrance. Daughters often specialize and then primarily act as guards or as foragers who provision the cells. In related species these duties are sometimes related to the age of the bee. The workers live as adults for only 3-4 weeks, while the foundresses life span can be up to one year—she can live until autumn. In late summer workers provision some larger cells with more pollen and nectar, eggs laid in these cells become foundresses. Males usually emerge no earlier then mid-August. These males then mate with the next year's foundresses (Chandler 1955).

Throughout the summer new generations of workers emerge and the nest continues to grow until males and queens are born. Large nests may contain 40 cells (Chandler 1955).

All sweat bees (Halictidae) have similar life cycles to that of *H. ligatus*. Whether they are solitary or not the females mate in the fall and then overwinter and begin new nests the following spring. However, in other bee families only larvae or pupae may overwinter and then emerge as adults the fallowing spring.

Studies Indicating Native Bees are Beneficial as Crop Pollinators

Native bees pollinate much like honey bees. In 2000, native bees provided about $3 billion worth of pollination services in North America (Vaughan et al. 2007). In part due to the recent declines in honey bees, there has been a growing interest in native bees as pollinators of crops. Some studies have found that in certain heterogeneous agricultural settings native bees can provide much of the needed pollination service. Honey bees cannot pollinate certain crops as effectively as some native bees. For instance, longer-tongued bees, such as some bumble bees can pollinate deep flowered plants such as red clover, more adequately than shorter tongued honey bees. Honey bees also cannot adequately pollinate certain crops such as potatoes and tomatoes, which require “buzz pollination” (Goulson 2003). However, bumble bees and some solitary bees can buzz pollinate--by shaking their flight muscles they shake the pollen in the flower loose. Additionally, for some crops (apples, cherries, squash, watermelon, blueberries, and cranberries) native bees are more efficient pollinators than honey bees on a per bee basis (Vaughan et al. 2007). In climates where wet and cold weather is common, bumble bees can be important crop pollinators because they continue to forage in the cold and wet, while honey bees do not (Goulson 2003).

In New Jersey and Pennsylvania, researchers studied crop pollination on both conventional and organic farms (Winfree et al. 2007a). They observed significantly more crop visitation by wild bees then honey bees on peppers and tomatoes. However, wild bee and honey bee visitation of melons was not significantly different. Interestingly, they found that 62% of the flower visits they observed were by wild bees not by honey bees. Flower visitation rate is the most important factor determining the amount of actual pollination taking place. Consequently, it can be assumed that wild bees in this study provided more pollination services than honey bees.

These researchers also created a model based on the bee pollination data they had collected and predict that native bee pollination alone was sufficient for watermelons at over 90% of the farms studied. In contrast, honey bees provided adequate pollination services of watermelon at only 78% of these farms (Winfree et al, 2007b). Interestingly, at the majority of the farms just one group of native bees, such as “small bees,” or bumble bees alone, provided enough pollination for the watermelons. These results show that in certain agro-ecosystems native bees can provide enough pollination services for crops if honey bees continue to decline.

Researchers in northern California studied wild bees as pollinators of field tomatoes (Greanleaf and Kremen 2006). These tomatoes are generally considered self-pollinators and therefore should not require insect mediated-pollination. However, when the wild bees visited the tomatoes, the tomatoes tended to be larger, and there was a greater number of tomatoes per plant. Less than 1% of the bee visits were by honey bees. Two species of native bees were the primary pollinators. One of them was a bumble bee. It was found that the proximity of natural habitat to the tomato fields had a positive influence on the abundance of bumble bees visiting the tomatoes. The other common bee observed was a solitary ground-nesting species. The researchers did not see a relation between the abundance of this species and the crops proximity of natural habitats. This may be explained by the differing life histories of these two species. Bumble bees usually nest in abandoned rodent burrows. These burrows may be more scarce on farms where rodents are often discouraged or eliminated. Therefore, nearby natural habitat may be important for providing nesting sites for this bumble bee species (Greanleaf and Kremen 2006). However, the solitary ground nesting bee may be more likely to nest on the farm in places such as drainage ditch embankments. Consequently, nearby natural habitat may not be as important for this bee species because it does not need to nest there (in fact, the researchers did not figure out what the factors limiting this species are). Due to these observations, the researchers concluded that it is very important to understand the life history and the variety of needs of the diversity of wild bees that provide crop pollination if one wants a farm or landscape to be able to sustain them.

Shuler et al. (2005) studied the pollinators of squash and pumpkin on 25 farms in Virginia, West Virginia. and Maryland. They found that the squash specialist *P. pruinosa* was the primary pollinator. It was found at more sites and at greater abundances than honey bees or any other native bees (of which bumble bees were the most common). In fact, across sites, *P. pruinosa* was over three times more abundant than honey bees and over two times more abundant than bumble bees. *P. pruinosa* also visits flowers more quickly and disperses the pollen greater distances than honey bees. When the farmers were interviewed, all were aware that their squash and pumpkin crops required insects for pollination. However, most assumed they were receiving the needed pollination services from either honey bees or bumble bees. Several farmers had heard of *P. pruinosa*, but none of them were aware that *P. pruinosa* was present on their farms. This indicates that many farmers have little awareness of native bees.

Factors Harming Native Bees

Like honey bees, native bees can be negatively impacted by human activities. Such activities include removal of flowering resources and nesting habitat, spraying of herbicides and pesticides, and monoculture-based agriculture in general.

Today's landscaping and farming practices often seek to remove as many weeds and flowering plants as possible. Many solitary bees have small flight ranges of up to 150-600 meters depending on size (Gathmann and Tscharntke 2002, foraging distance solitary bees), and cannot survive in landscapes where they must fly long distances to find flowering resources, such as on large industrial scale farms. However, it should be noted that the bumble bees (which are larger than most other bees) can fly greater distances. Depending on the species, this can range from 500 m to 1750 m (Walther-Hellwig and Frankl 2000). Consequently, for these bees, field size could be less of a limiting factor.

Many native bees have long flight seasons (all summer long for *H. ligatus*). However, many crops only flower for one or two weeks. As a result, a monoculture does not provide enough forage for bees to survive and other flowers are needed to sustain them.

When farmers spray pesticides they first close the honeybee hives so that they do not get poisoned. However, this possibility does not exist for wild bees. The bees can either get killed by direct contact with pesticides, or from foraging on pesticide-laden plants. Many of our native bees are much smaller than honey bees and a lower concentration of pesticides is sufficient to kill these smaller bees (Pollinator cons. hanbok). Herbicides also indirectly affect bees by reducing the pollen resources. For example, in a study in Canada, fewer native bees were present in fields of genetically modified, herbicide-resistant canola than in conventional and organically grown canola fields (Morandin et al. 2005). Presumably this was due to the fact that more herbicides were applied to the genetically modified canola fields and they had fewer (non-canola) flowering resources. It is important to note that canola benefits from pollination, and the GM canola received the least pollination from native bees. The researchers concluded that for GM and conventionally grown canola, native pollinators alone could not provide adequate pollination services. However, they did adequately pollinate the organically grown canola.

Management Considerations for Native Bees

Native bees need flowering resources in addition to the crops that are a farmer is growing, most notably when the agricultural practices create monocultures. The most important factor that is beneficial for native bees on farms is the presence of a significant amount of wild habitat surrounding and within the farm (Eric Mader personal communication). Apparently this factor is much more important than whether the farm is managed organically vs. conventionally. For example, a study in New Jersey found no difference in the diversity or abundance of native bees on organic and conventional farms (Winfree et al. 2007a). It is important to note that all these farms were of similar size and were surrounded by similar amounts of natural habitat. In essence, all these farms were part of similar heterogeneous landscape.

Researchers in California's central valley studied watermelon pollination on three different categories of farms: "organic close," "organic far," and "conventional far;" the distance refers to the distance to natural habitat (Kremen et al. 2002). No close conventional farms existed within the area they were studying. None of the "conventional far" farms received enough pollination from native bees, and they relied on managed honey bees for pollination. Approximately 50% of the "organic far" farms received adequate pollination from native bees and 80% of the "organic close" farms received adequate pollination from native bees and had the highest native bee diversity and abundance. The "organic close" farms did not rely on managed honey bee hives. This study demonstrates how the homogenous landscape created by large conventional farms does not provide suitable native bee habitat.

In an area such as California's Central Valley it is not quite fair to say it does not matter whether the farms are organic or conventional in respect to native bee diversity and abundance. This is because organic farms tend to be smaller than their conventional counterparts, which caters to the creation of bee-friendly heterogeneous landscapes. However, the researchers did say "… that natural habitat is truly a much more important predictor of variation in pollination services in this landscape than farm management type" (Kremen et al 2004, p. 1116).

Contrary to the above results, researchers in Germany found that farming practices were important factors influencing bee populations. Fallow strips (non-cultivated areas containing flowering plants) adjacent to organically managed farms harbored greater native bee diversity and abundance then those adjacent to conventionally managed farms (Holzschuh et al. 2008). These researchers believe that a greater amount of organic fields on a large scale could enhance pollinator communities. They found that an increase of surrounding organic agriculture from 5% to 20% increased bee diversity by 50% on "fallow strips." Thus, the organic crop management presumably had a positive affect on the wild bees.

Hedgerows containing flowering plants and flowering field margins also provide important forage for bees. It is important to note that on a smaller scale flowering shrubs and flowers (particularly native) in lawns and at yard edges are also important for bee conservation. Low-growing plants such as clovers in lawns can also be helpful for bees (Sam Droege, personal communication). For example, in the U.K., researchers found that naturally regenerated (un-cropped) field margins could be beneficial for conserving bumble bees (Kells et al. 2001). These margins provided many more foraging opportunities for bees than cropped field margins.

Early flowering willows and late flowering asters and goldenrods are especially important on farms to provide additional forage for bees (Eric Mader, personal communication). In the New Jersey/Pennsylvania study, the researchers also found that there was a positive correlation between native bee abundance and diversity and the abundance of flowering weeds found in fields on the farms studied (Winfree et all 2007a). Other researchers have also found that generally there is a positive relation between flower diversity and the abundance of bees (Kells et al. 2001). The most simple management scheme for farms surrounded by a considerable amount of natural habitat may just be to maintain some areas that are only mowed annually and contain wildflowers (Droege, personal communication)

The majority of native bees are ground nesting. Consequently, they cannot nest in plowed soils. However, tilling is a weed control practice used by some farmers (especially organic). Shuler et al. (2005) observed that significantly higher densities of the ground nesting be *P. pruinosa* occurred on farms that practiced no-till agriculture presumably because some nests are inadvertently destroyed through plowing. Due to the fact that there are so many ground-nesting bees, it may be beneficial to maximize untilled ground. Additionally, it could be helpful if semi-bare, well-drained soil is available for bees to nest in. Providing piles of sandy soil could also prove helpful (Vaughan et al 2007).

Many sources also recommend putting out nesting blocks for nesting bees such as leaf cutter bees (e.g. Vaughan et al 2007, Shepherd et al. 2003). These are wooden blocks with a variety of holes drilled in them. Wild bees do readily except these nest blocks—depending on where they are placed (personal observation). However, they must be cleaned, or destroyed every 3 years, to prevent parasites and fungus from invading the blocks (farming for bees). For crop pollination purposes, it may not be helpful to put them out unless one is willing to regularly clean them (Eric Mader, personal communication).

The abundance of individual native bee species varies greatly from year to year, so biologists predict that in order to have assurance of crop pollination every year having a set of at least 20 or so common native bee species is necessary(Kremen et al. 2002)—that is, if one is not only relying on honey bees. For this reason it may be important for farmers and landscape-scale planners to take the above-mentioned management plans into consideration if they want to maximize the benefits of conserving a diversity of native bees.

Conclusion

Clearly native bees are often-overlooked, but important pollinators. Many researchers have shown that under certain conditions native bees can even provide sufficient crop pollination, in which cases honey bees would not be necessary. This is not to say that honey bees are not needed for crop pollination, in fact, without them many of our large-scale farms would receive little if any insect pollination. However—in contrast to media portraits of the honey bee declines—all would not be lost if drastic declines were to continue. Native bees would benefit from more diversified landscapes (landscape-scale planning), which could increase their populations. This could be done largely through educating land owners and farmers about native bees so that they could be sensitive to their needs.

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